Hub

Technology Hub

Rapid Prototyping and Time Compression

for

The Institution of Mechanical Engineers

20th September 2000 - 1800 hrs

Professor Chris R. Chatwin – Technology Hub Research Director

School of Engineering & Information Technology
University of Sussex

Technology Hub

Technology Hub Vision

To provide world class advanced engineering and Information technology knowledge to businesses in the region, thus enabling them to prosper and improve the regional economy

The Message

TURNING INFORMATION AND TECHNOLOGY INTO BUSINESS KNOWLEDGE

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Local Company Aims

- Advance the manufacturing processes.
  - For Medical, Automotive, Communications, Instrumentation, Sensors and Signal Processing.
- Use the best Simulation and Design tools.
- Adopt Time Compression Methods.
  - To speed up new products to market.
- Find more Graduate Staff for the local industries.

The Initial Themes

- Internet Data Communications & e-commerce
- Industrial & Automotive Electronics
- Micrometric Electronic Systems & Sensors
- Time Compression & Rapid Prototyping
- Image Processing & Photonics
- Continuing Professional Development

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Concurrent Engineering

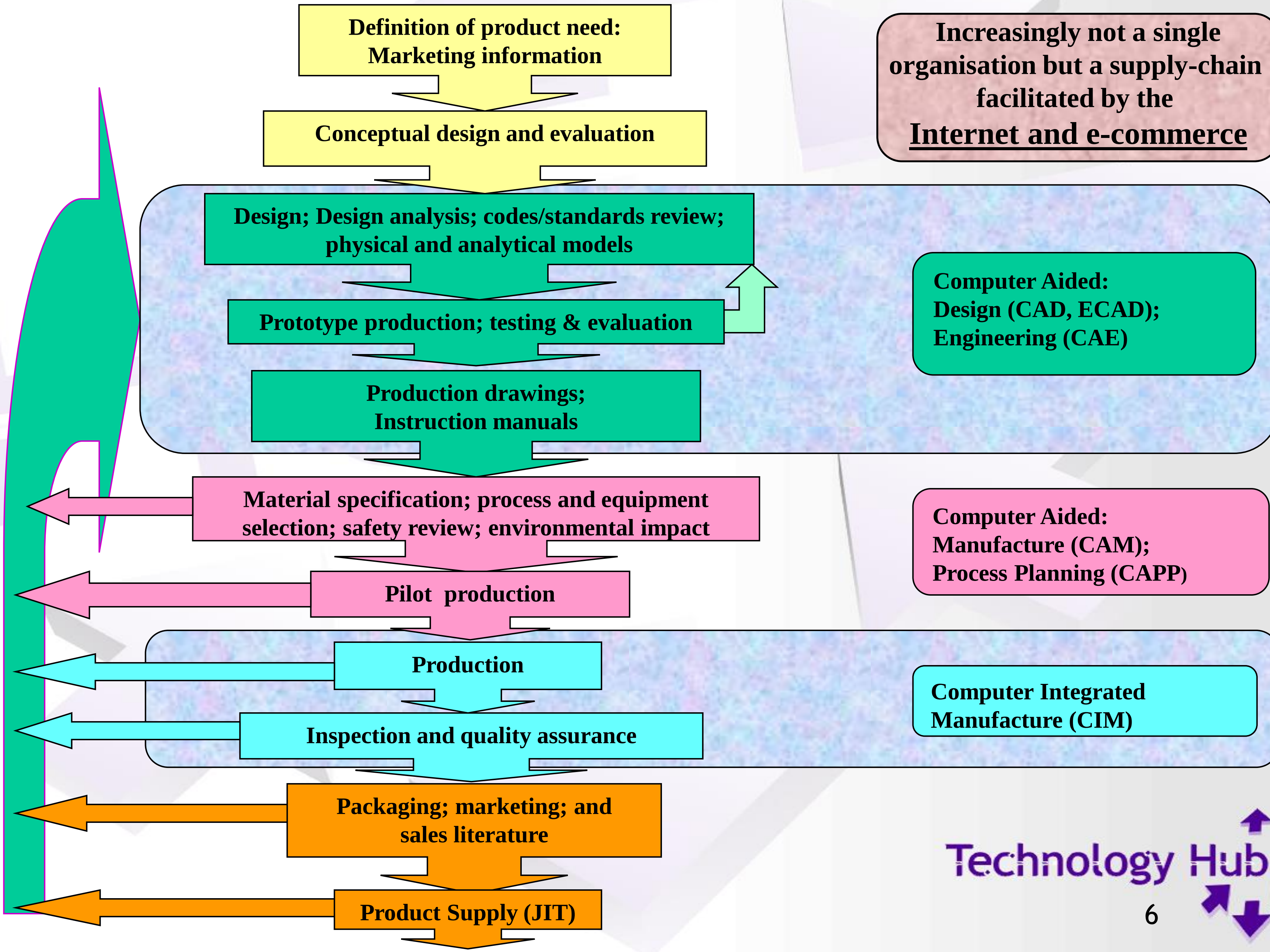


Figure 16a: **CFD optimisation of flow.**

Figure 16b: **CAD design of castings.**

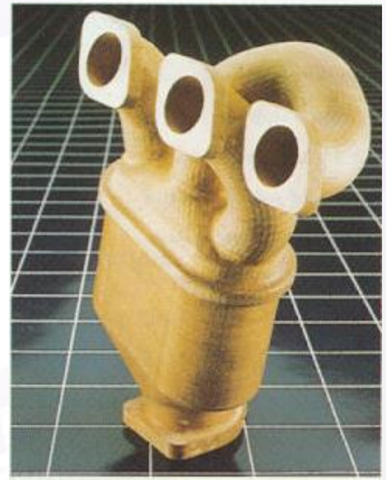
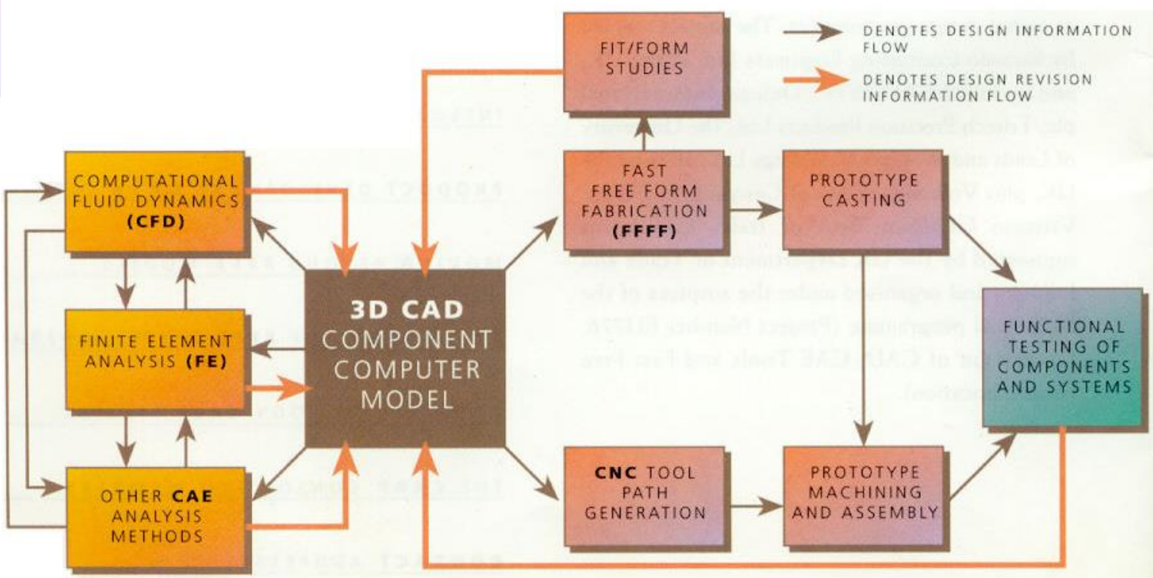


Figure 16c: **LOM models.**

Figure 16d: **Investment casting using LOM and SLS FFFF patterns.**

Courtesy of Ricardo CARP project



Technologies Enabling Product Innovation - Summary

- Rapid Prototyping - manufacture by layering processes:
  - Stereolithography
  - Selective Layer Sintering (SLS)
  - Laminated Object Manufacture (LOM)
  - Solid Ground Curing
- Small batch programmable rapid manufacture with lasers
- Micro-Engineering – Prototyping and Manufacture
  - Additive - fabrication
  - Subtractive – machining

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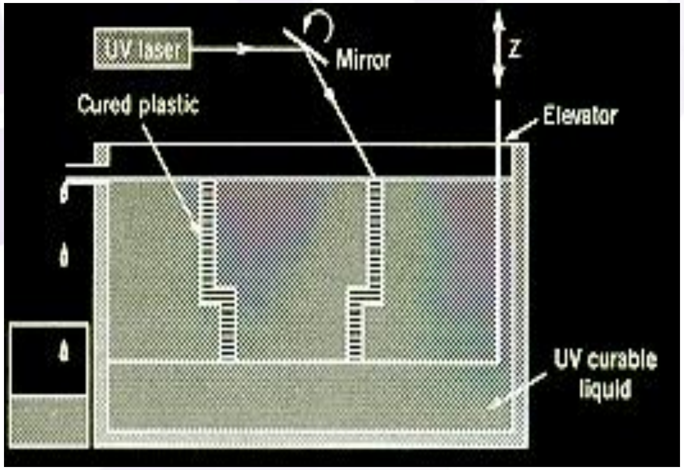
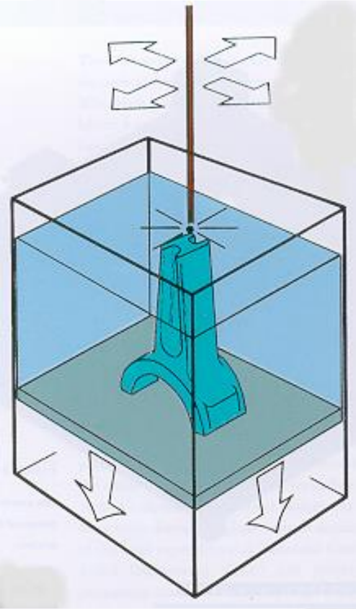
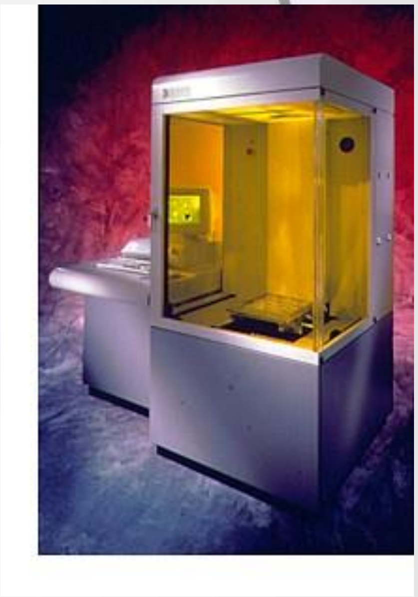
Scanning Beam Stereolithography

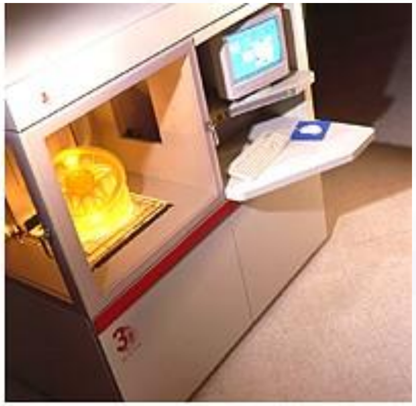


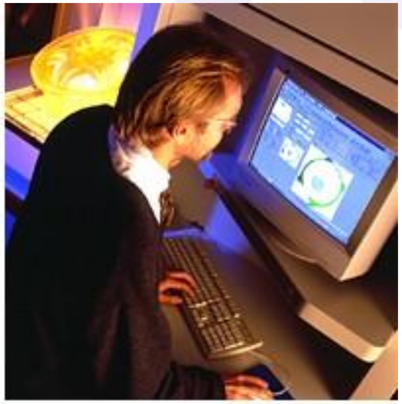


3D Systems SLA
3500 Series



3D Systems Scanning Beam Stereolithography System





SLA 7000 Series - Dual spot laser technology gives greater speed

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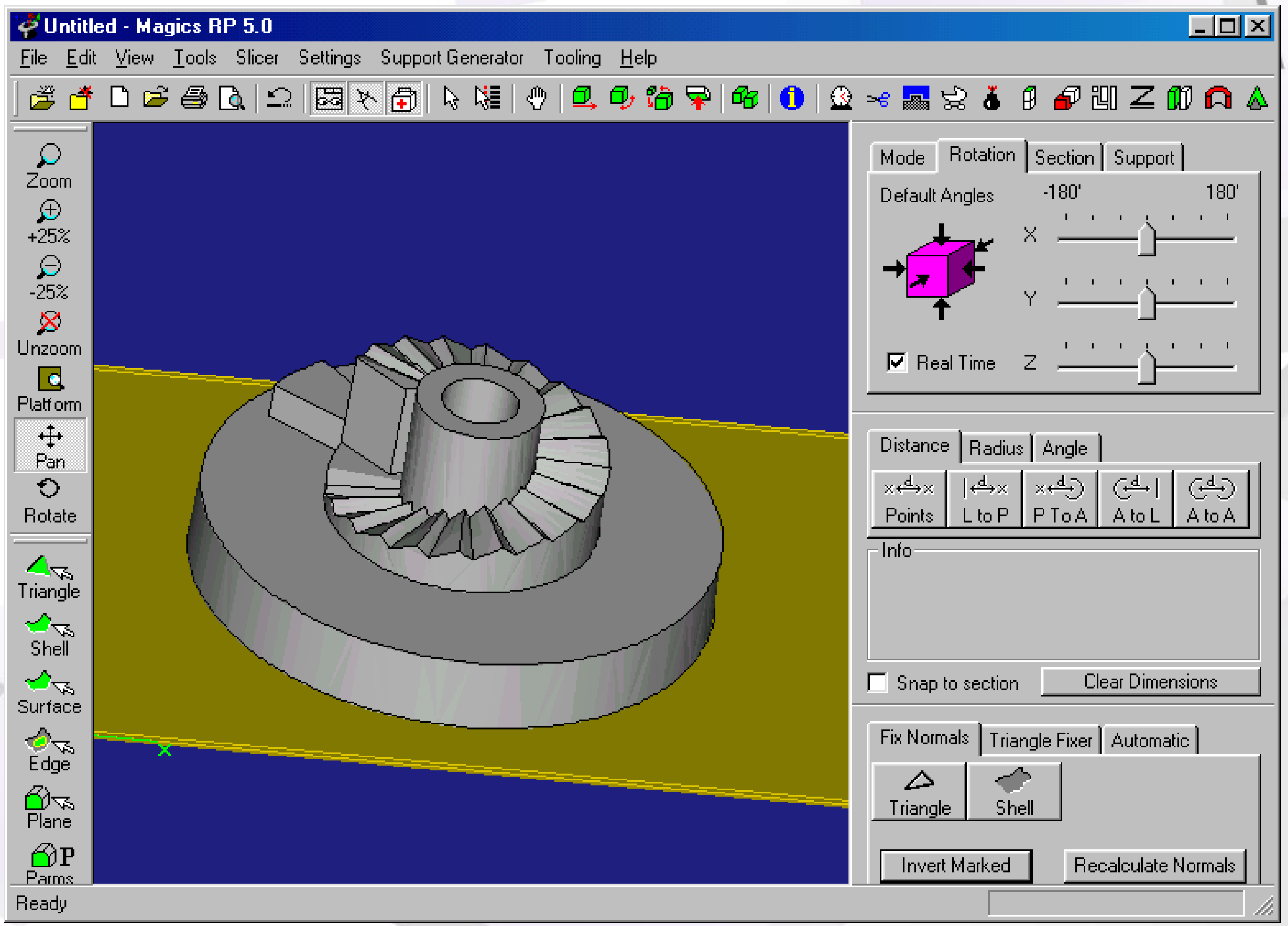
STL Interface



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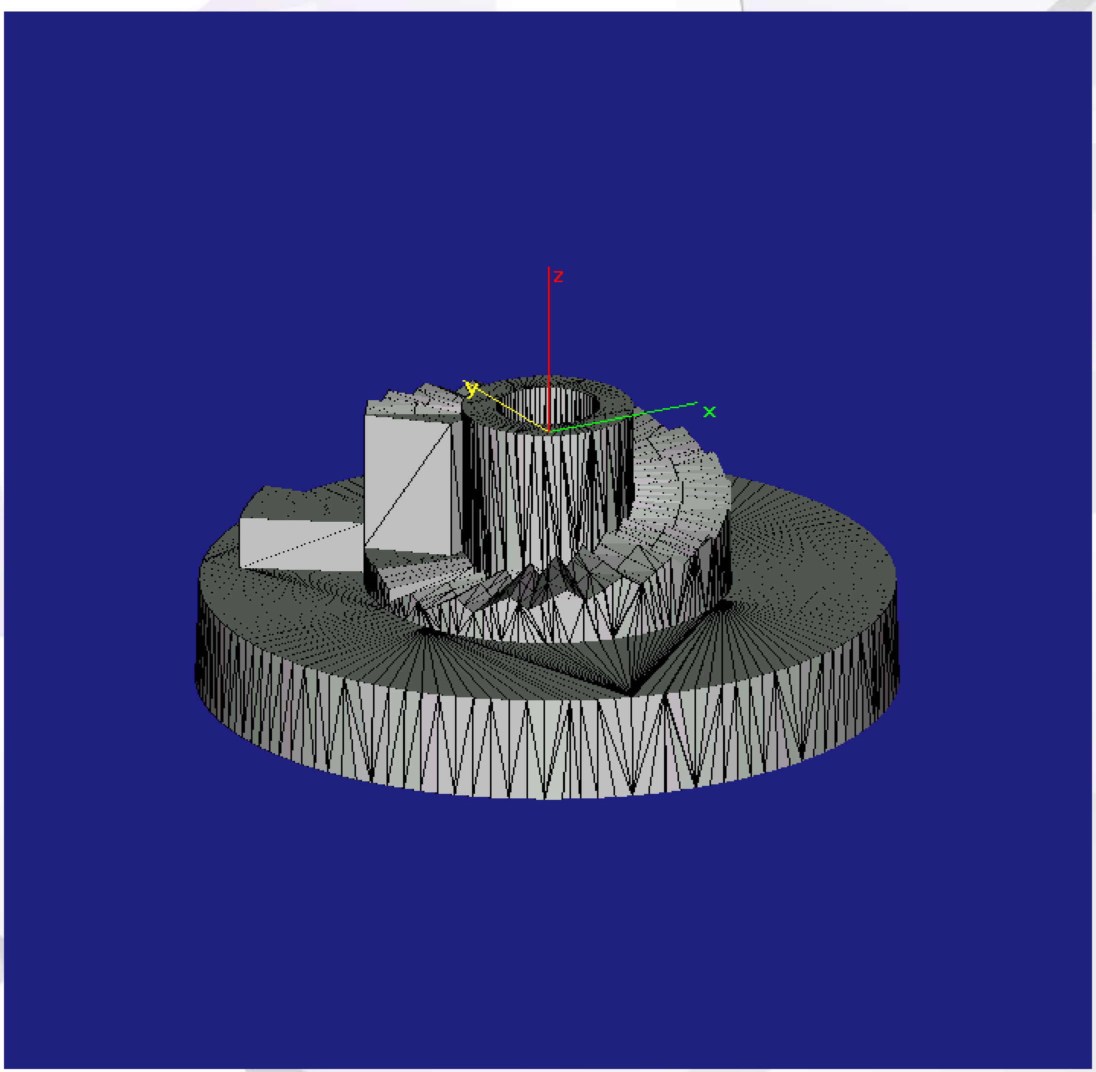
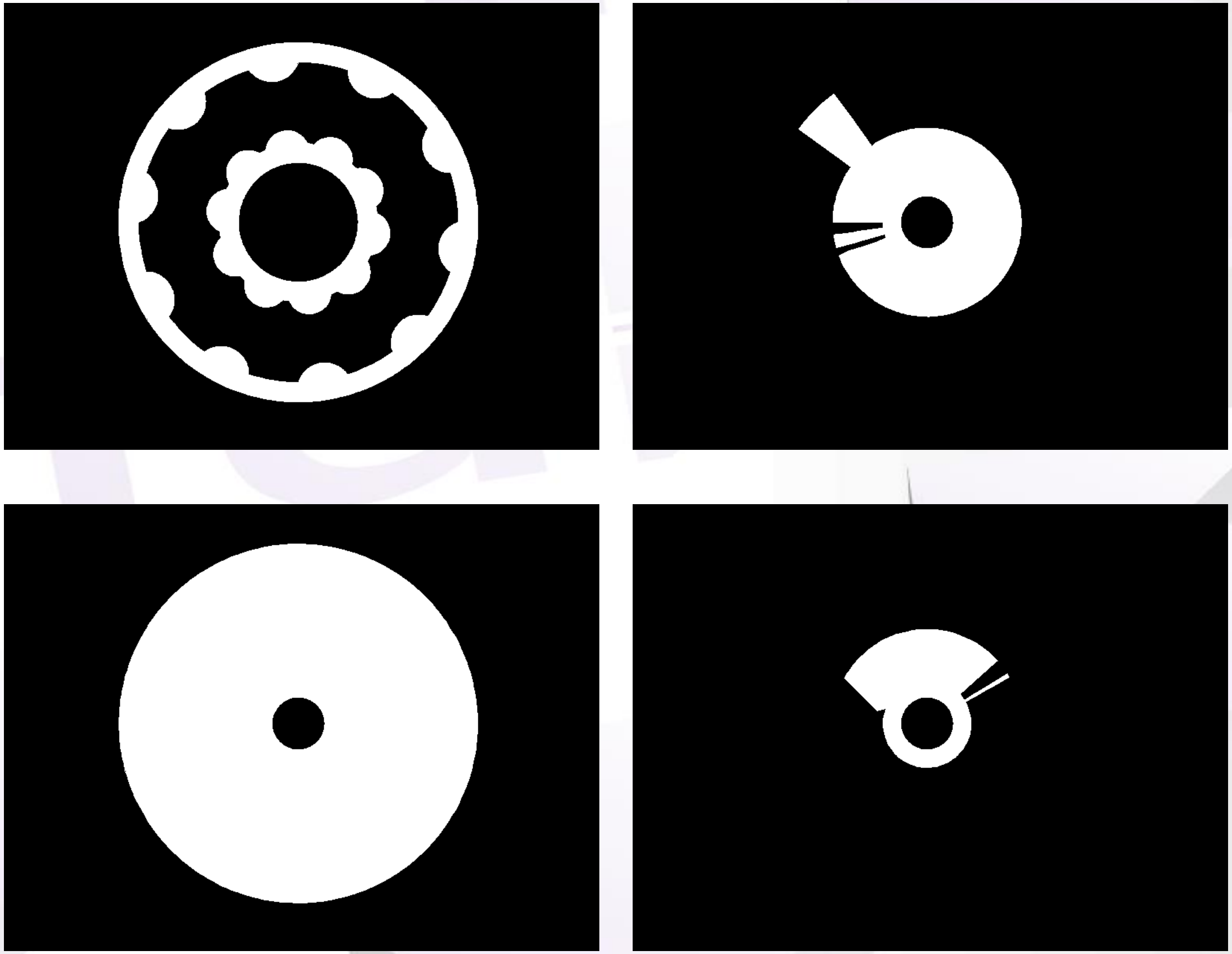
STL triangle format

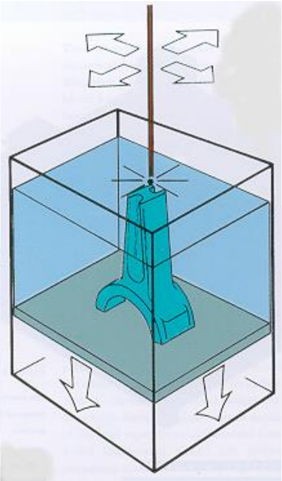


Slices from STL Model



Rapid Prototyping

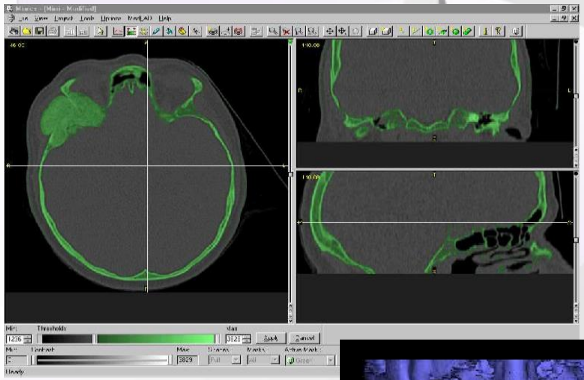
Stereolithography



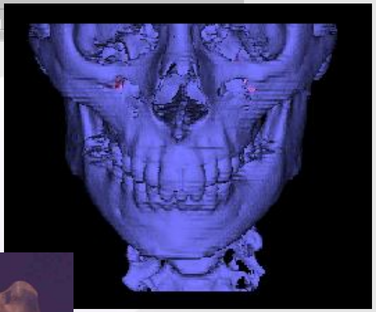
Courtesy of Ricardo

Sussex SLA 250

Magnetic Resonance Imaging

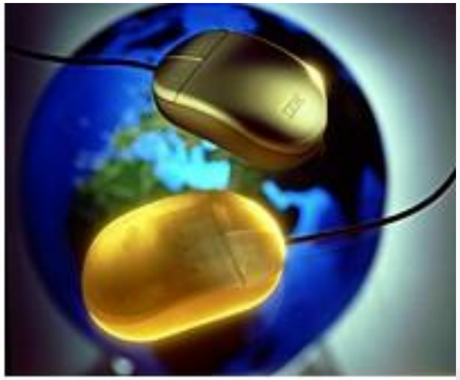


3D Model



SLA Model

Daewoo manifold



Logitech - From quote to working prototype in 7 days - 3D Systems

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Sussex SLA250 Stereolithography

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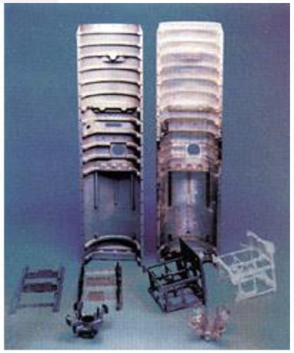
Products Using 3D Systems SLA Machine

16 weeks to 39hrs; £22,000 to £1200

Rover - Injection manifold for new engine - 90% lead time reduction



Texas Instruments -
New shell casing – 20 off
$450,000 saving on tooling

Oldsmobile Aurora – 500 ABS parts
9 weeks to 4 weeks - TC 50% Bose Corp

Johnson Controls for Coca-Cola - 11 hours build time, 1 week design

Electrolux - Vacuum Cleaner
50% lead time reduction

Black & Decker - Shrub Trimmer
100 days 30 functioning prototypes

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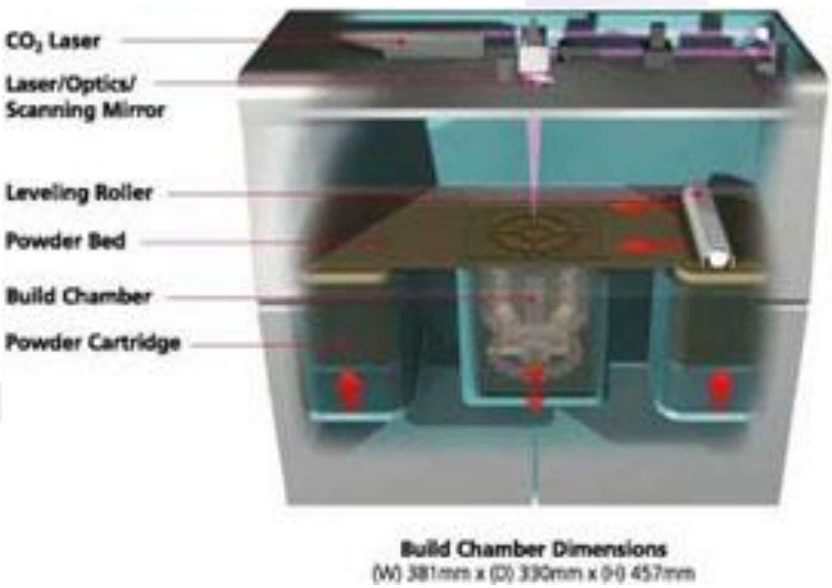
DTM Corporation SLS system



1. Spread a layer of powdered material. As the process begins, a precision roller mechanism automatically spreads a thin layer of powdered SLS material across the build platform.

2. Sinter a cross-section of the CAD file. Using data from the STL file, a CO_2 laser selectively draws a cross section of the object on the layer of powder. As the laser draws the cross section, it selectively "sinters" (heats and fuses) the powder creating a solid mass that represents one cross section of the part.

Sinterstation 2500*plus*

1) More material choices: plastic, elastomer, metal, or ceramic

2) More application options: functional prototypes, tooling, patterns—even final parts.

3) Build chamber dimensions (W) 381 mm x (D) 330 mm x (H) 457 mm

DTM – SLS - Materials

Functional Plastic Prototypes - Create visual models, functional prototypes, durable patterns—even plastic parts for final use. *DuraForm Polyamide and DuraForm Glass Filled*

Durable Elastomer Prototypes- Produce, flexible, rubber-like prototypes and parts. *SOMOS 201*

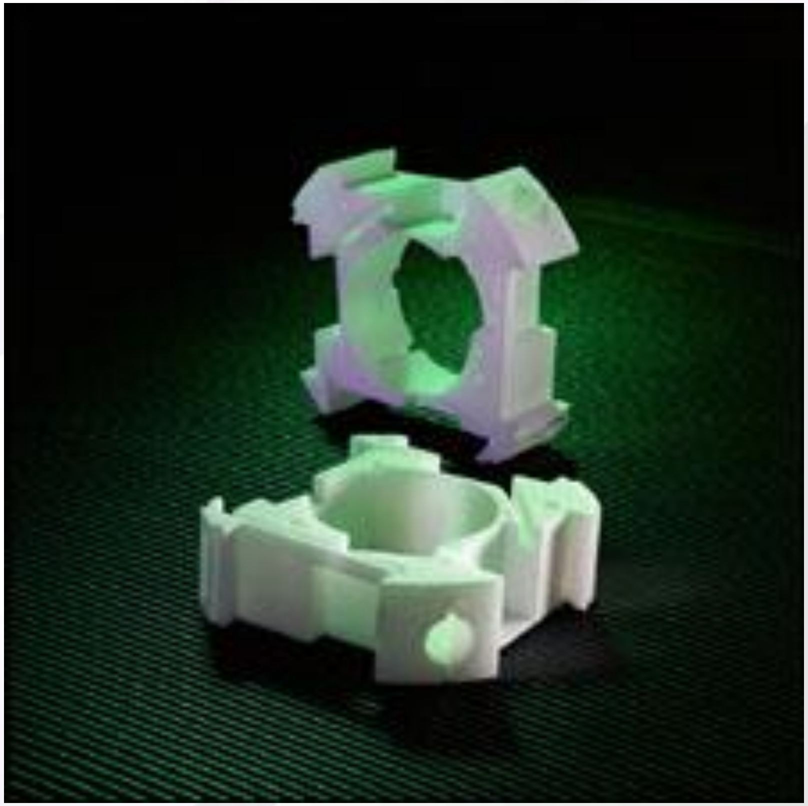
Metal Tools- Rapidly prototype—or rapidly manufacture—metal molds and tools. *RapidSteel 2.0 and Copper Polyamide*

Casting Patterns, Cores, and Molds - Quickly generate investment casting patterns or sand casting cores and molds. *CastForm Polystyrene, SandForm Zr, SandForm Si*

SLS Material: DuraForm PA™ - Plastic

Summary:
NASA used its in-house Sinterstation® system and DuraForm PA™ to quickly produce a **"science cup,"** a tray-like fixture that holds a variety of instruments, wiring, and batteries within a hockey puck-sized, self-contained spacecraft called the Free Flying Magnetometer (FFM).

Using a Sinterstation system helped NASA solve the challenges listed above. In addition, the organization saw an additional benefit: it saved money. The parts generated on the Sinterstation cost only **300 US $ to produce**, compared to the **3,000 to 5,000 US $** it would have taken to fabricate the parts using traditional machining methods in aluminium, steel, or titanium



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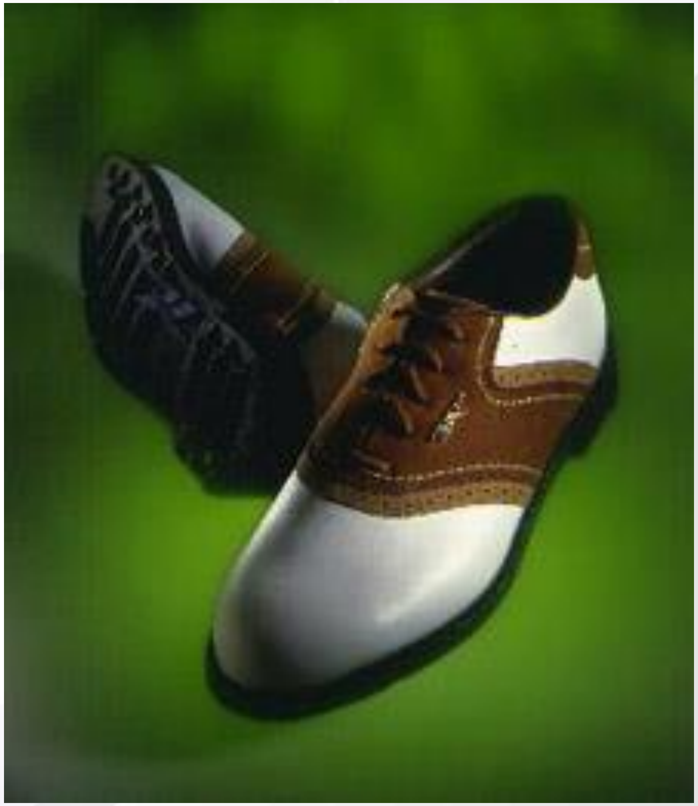
SLS Material SOMOS 201 - Elastomer

Summary
Reebok's Golf Division was in the early stages of developing a new spikeless golf shoe sole design and needed a fast, cost-effective way to create a flexible, testable prototype. Using traditional prototyping methods (standard tooling and injection moulding) would have taken **30 to 60 days and cost Reebok $3,500 to $4,000 per prototype**.

Reebok took another approach and prototyped the new sole design on its in-house Sinterstation system using SOMOS® 201. The process took just **seven hours and about $250 worth of SOMOS 201**. The prototype soles were affixed to a pair of golf shoes and worn by an experienced golfer for two rounds of golf.



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SLS Material – Copper PA

Summary:
Rover's Rapid Prototyping and Tooling Department spent two months studying DTM's Copper PA material. One of the parts selected for production and study was an automobile glass guide measuring approximately 90 mm x 60 mm x 25 mm.
The intended production material was nylon 6,6.

Rover used this Copper PA tool to shoot an initial run of **33 polypropylene parts**. Once confident that the tool was working properly, it shot **another 117 nylon 6,6 parts**, some of which were installed on prototype vehicles. Rover was pleased to note that the Copper PA tool **withstood an injection moulding temperature of 285°C.**

SLS Material: RapidSteel

SLS Material: RapidSteel® 2.0

Summary:
3K Warner prototyped this turbocharger housing on a Sinterstation® system using RapidSteel 2.0.

The part was assembled within a turbocharger unit and put through test bench trials simulating severe conditions. Testing included worst case scenarios and full throttle runs that lasted several hours.

The RapidSteel 2.0 prototype **endured temperatures as high as 570 °C** and performed throughout the testing with no problems.

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SLS Material - Sandform

Summary:
When Woodward Governor Company (WGC) needed a casting of a new aircraft fuel control system for a gas turbine engine, it faced a formidable challenge: finding a process that could produce a large, complex casting within a very tight time frame. The project required extraordinary efforts from four companies and provided the ultimate test for DTM's Sinterstation® and SandForm™ material.

The time and money savings realized in this project were remarkable. Conventional tooling would have typically required **35 weeks**, just to generate the tools. Then it would have taken **another 12 weeks** to get the first casting. These times were **cut in half**. It took just two months to get the sand cores. What's more, the cost was only **20% of the cost** of conventional tooling.

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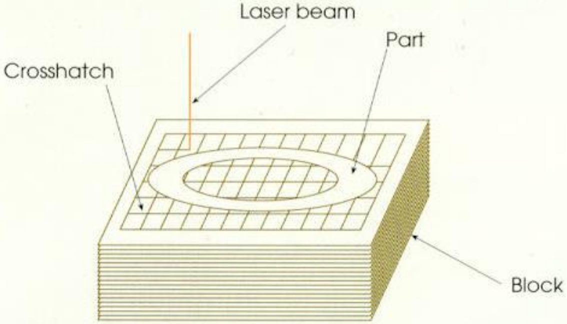
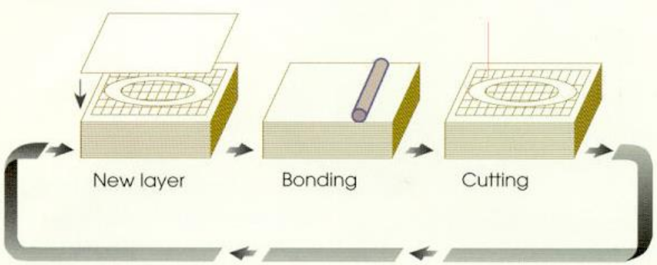
Laminated Object Manufacture - Helisys

LOM PROCESS

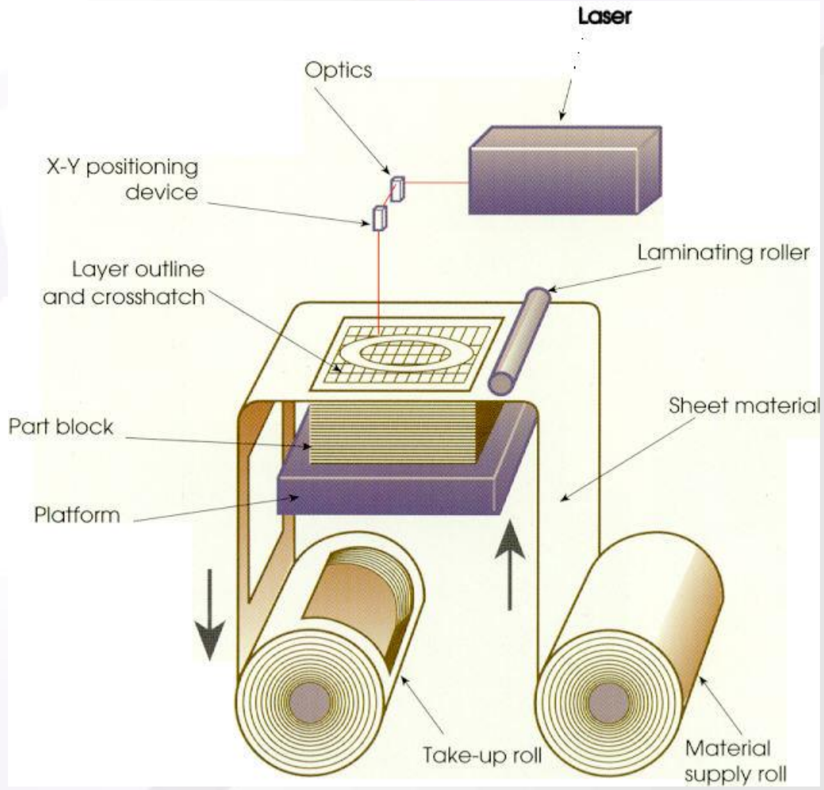
CAD data goes into the LOM system's process controller and a cross-sectional slice is created by the LOM software.



The laser cuts the cross-sectional outline in the top layer and then cross-hatches the excess material for later removal.



A new layer is bonded to the previously cut layer and a new cross section is created and cut as before. Once all layers have been laminated and cut, excess material is removed to expose the finished model.



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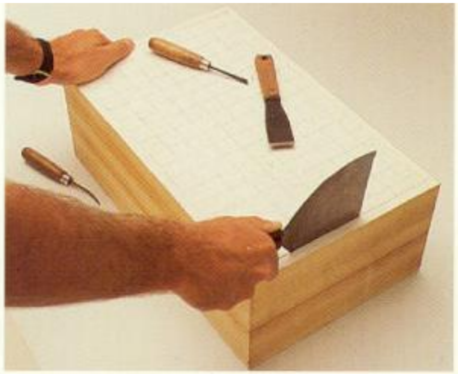
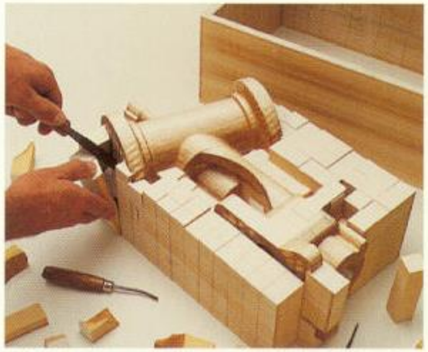
S P E C I F I C A T I O N

	LOM-2030	LOM-1015
MAXIMUM PART SIZE:	32" L x 22" W x 20" H	15" L x 10" W x 14" H
PART ACCURACY:	±0.010" X-Y-Z (relative feature location)	±0.010" X-Y-Z (relative feature location)
LASER:	50 Watt CO_2	25 Watt CO_2
LASER BEAM DIAMETER:	0.010"-0.015"	0.010"-0.015"
POSITIONING SYSTEM:	X-Y Positioning Table Moves the Laser Beam	X-Y Positioning Table Moves the Laser Beam
CUTTING SPEED:	Up to 24"/second	Up to 15"/second

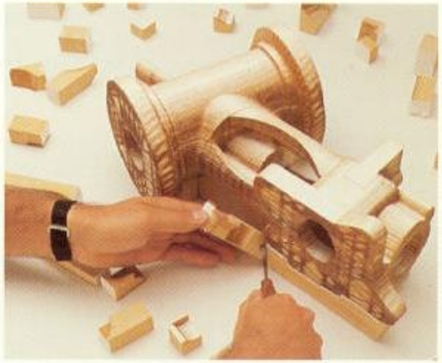
Laminated Object Manufacture



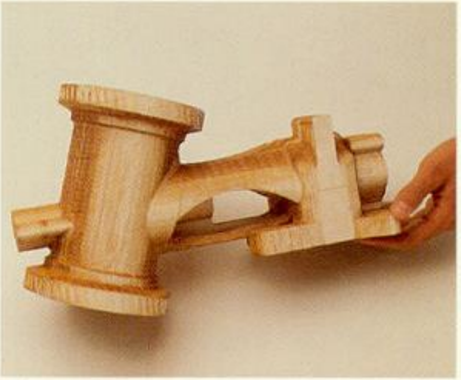
The laminated stack is removed from the machine's elevator plate.



The surrounding wall is lifted off the object to expose cubes of excess material.



Cubes are easily separated from the object's surface.



The object's surface can then be sanded, polished or painted as desired.

SAND CASTING
The LOM process can be used to produce solid cores or core boxes quickly by simply outlining the periphery of each cross-section. Using inexpensive LOM materials, the creation of large and bulky patterns is especially fast and cost-effective.

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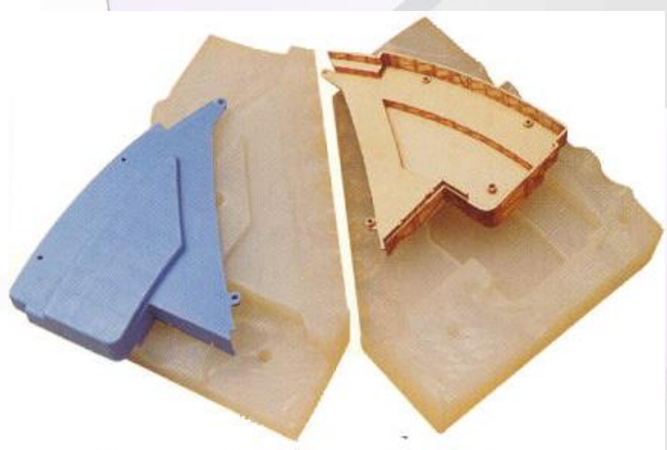
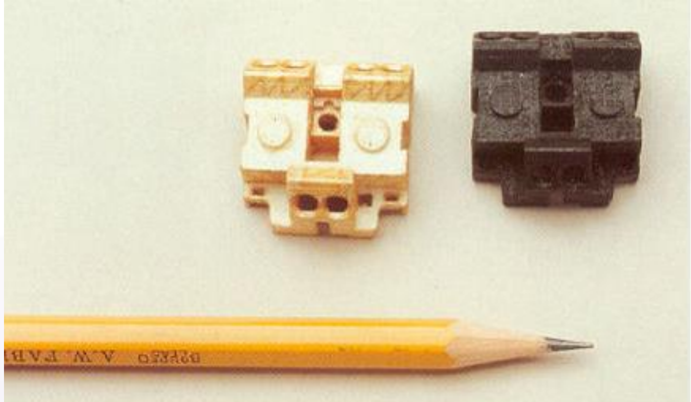
Laminated Object Manufacture



Silicon Rubber Moulding – Urethane or epoxy cast plastic parts



Spray Metal Moulds for prototype injection moulding

TECHNICAL SPECIFICATIONS

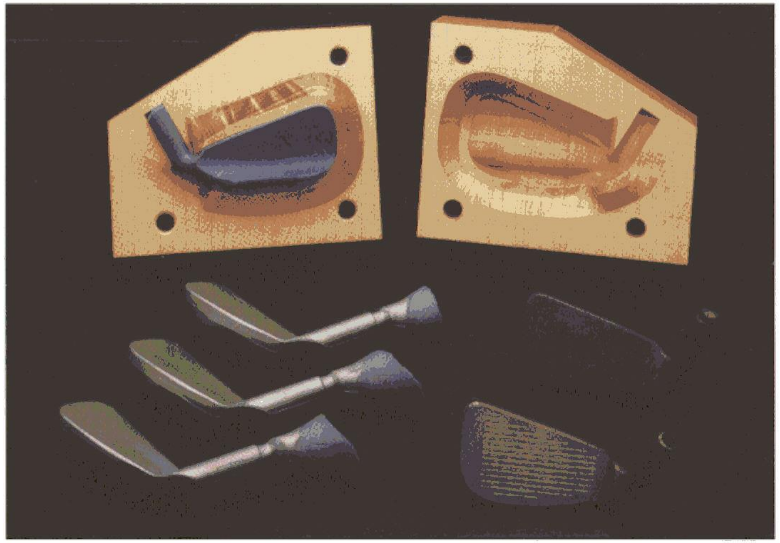
LOMPart™: Ballistic Projectiles
Company: Lufkin Industries, Inc.
Matchplate Dimensions (X-Y-Z): 17" x 12" x 3" (both plates)
Core Box Dimensions (X-Y-Z): 8" x 5" x 1.75" (both halves)
LOM System: LOM-2030
LOMPaper™: 0.0038" Double Layered
Matchplates: Data Preparation: 30 min. LOM Build : 35 hrs. Finishing: 8 hrs.
Core Boxes: Data Preparation: 30 min. LOM Build : 20 hrs. Finishing: 6 hrs.
Finishing Materials: Sanding lacquer sealer & lacquer spray

Application: Sand Casting
Matchplates were cast in sand and sand was injected into core box to produce over 400 prototype metal projectiles.

TECHNICAL SPECIFICATIONS

LOMPart™: Oversized 7-Iron Golf Club Head
Dimensions (X-Y-Z): 7" x 5" x 3.5"
LOM System: LOM-1015
LOMPaper™: 0.0038" Single Layer
Data Preparation: 30 min. LOM Build : 23 hrs. Finishing: 4 hrs.
Finishing Materials: Sanding lacquer sealer & lacquer spray

Application: Investment Casting
50 wax patterns were injected into the LOM golf club mold for the investment casting process. Resulting metal club heads were finished and tested on the golf course.



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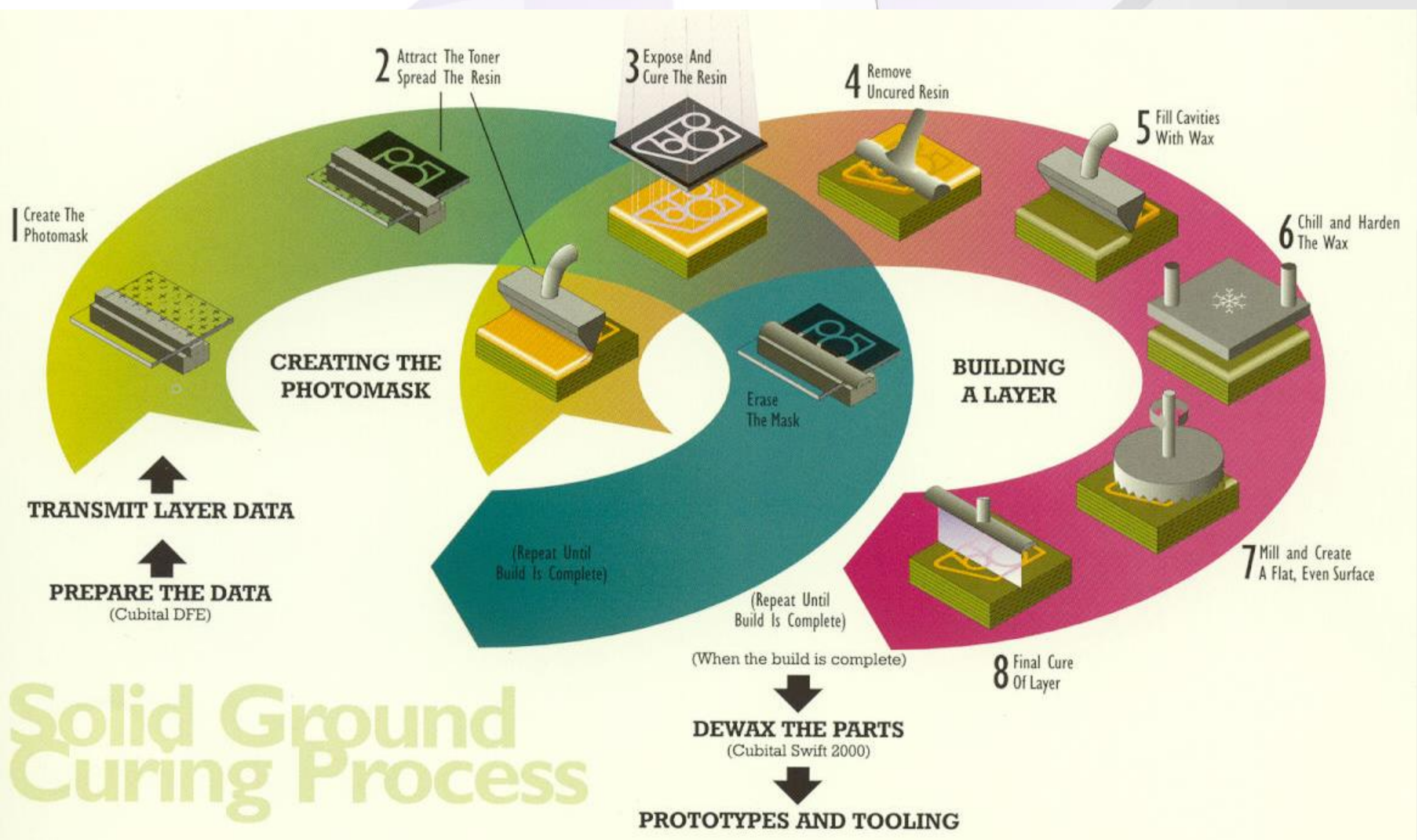
Solid Ground Curing - Cubital

SGC 5600 – Build Envelope 500x350x500 mm – resolution 0.1 mm

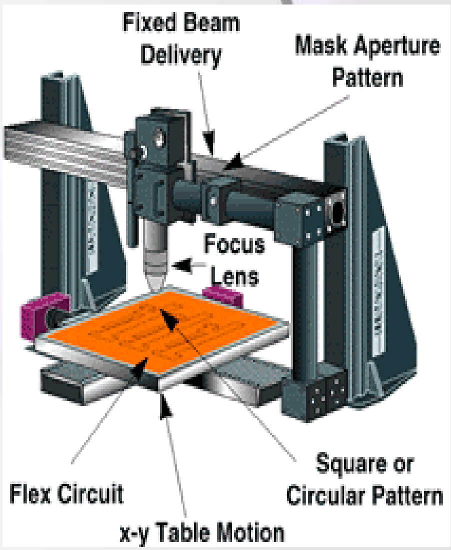


2 Attract The Toner Spread The Resin
3 Expose And Cure The Resin
4 Remove Uncured Resin
5 Fill Cavities With Wax
1 Create The Photomask
6 Chill and Harden The Wax
CREATING THE PHOTOMASK
BUILDING A LAYER
Erase The Mask
TRANSMIT LAYER DATA
(Repeat Until Build Is Complete)
7 Mill and Create A Flat, Even Surface
PREPARE THE DATA
(Cubital DFE)
(Repeat Until Build Is Complete)
(When the build is complete)
8 Final Cure Of Layer
Solid Ground Curing Process
DEWAX THE PARTS
(Cubital Swift 2000)
PROTOTYPES AND TOOLING

Computer Numerically Controlled (CNC) Beam delivery Systems

Laserdyne 550 Beam Director

Multiaxis: cutting, drilling, welding for manufacturers in aerospace, automotive and job shop industries



Laserdyne 890 Beam Director

Multiaxis: cutting, drilling, welding for manufacturers in aerospace, automotive and job shop industries

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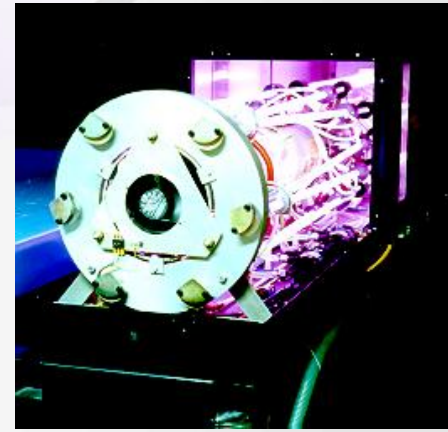
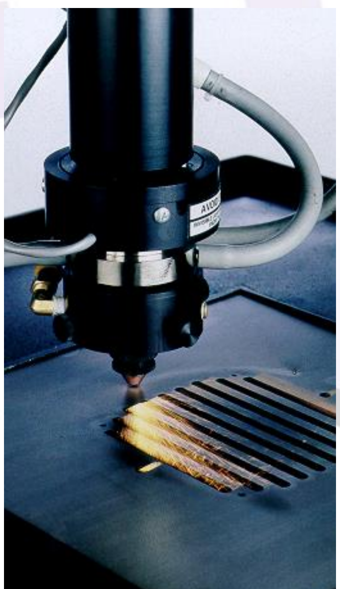
Small Batch Rapid Manufacture using Lasers

AF8P - 8kW Carbon Dioxide Laser can run CW or Pulsed up to 3.3kHz

AF8P- CO: 1 - 2.5kW Carbon Monoxide Laser can run CW or Pulsed up to 3.3kHz

MFK 1 kW CO_2 Laser





Case Hardening of a Camshaft

Weld Penetration in 12 mm SS

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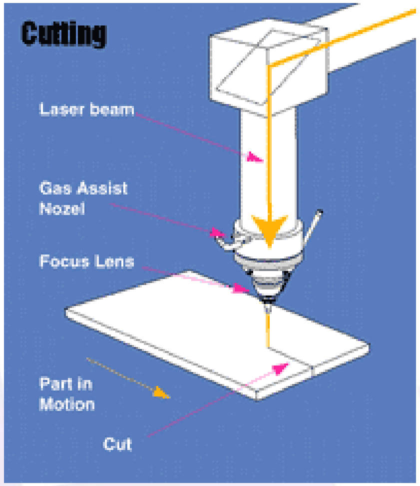
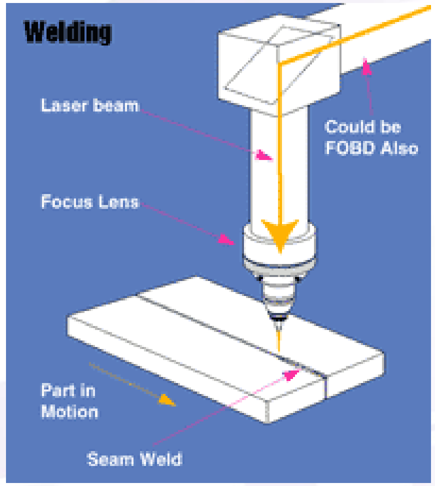
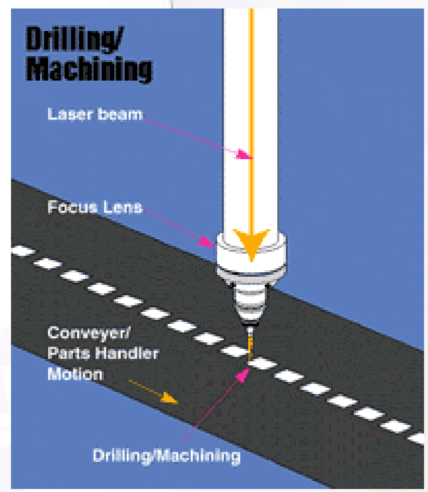
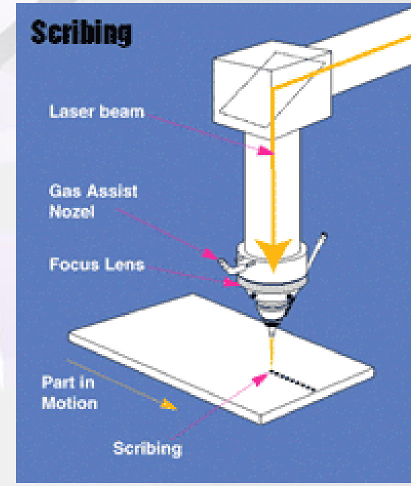
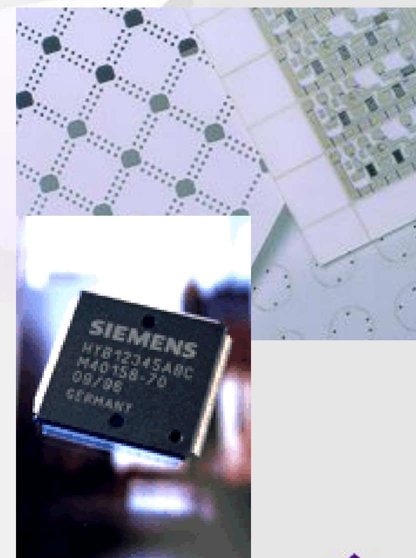
Rapid Programmable Manufacture Using Lasers



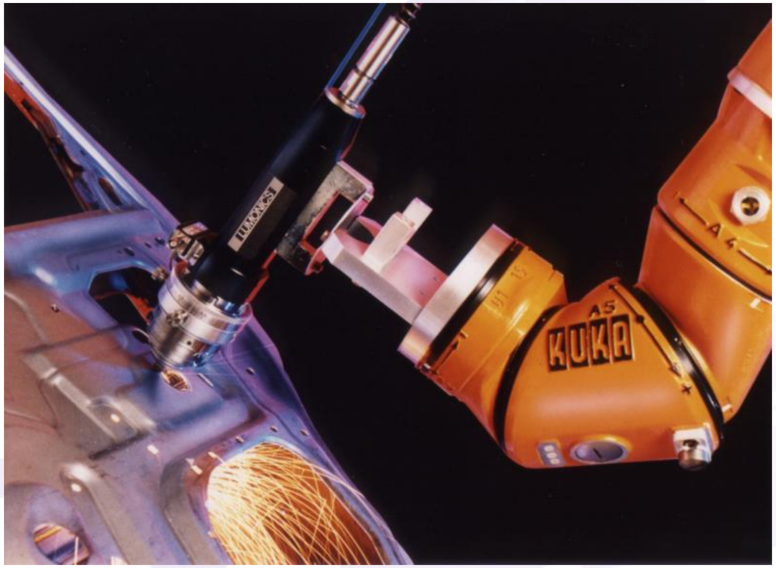


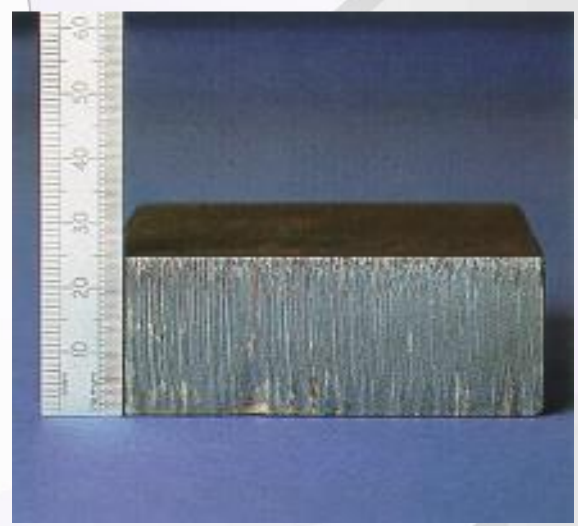




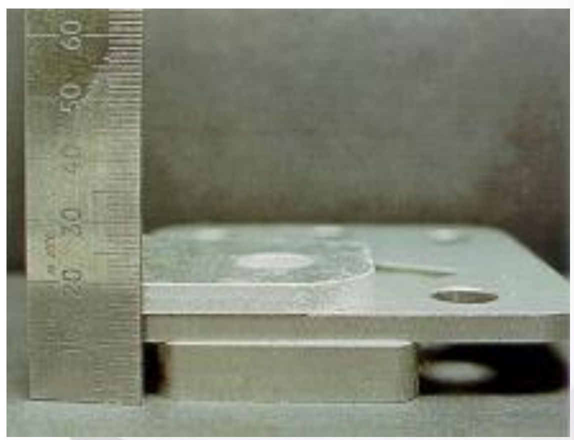


Laser Cutting

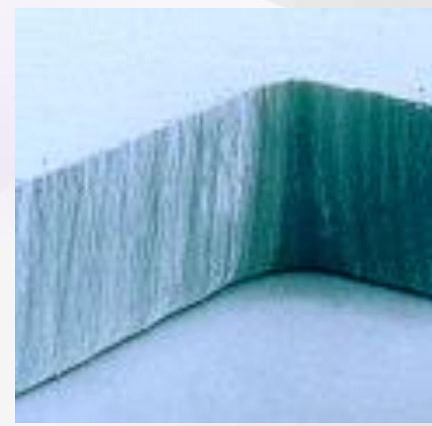




25mm Armour Plate



Inert gas (N_2) cut samples of 10 mm stainless, 5 mm stainless, 6 mm aluminium



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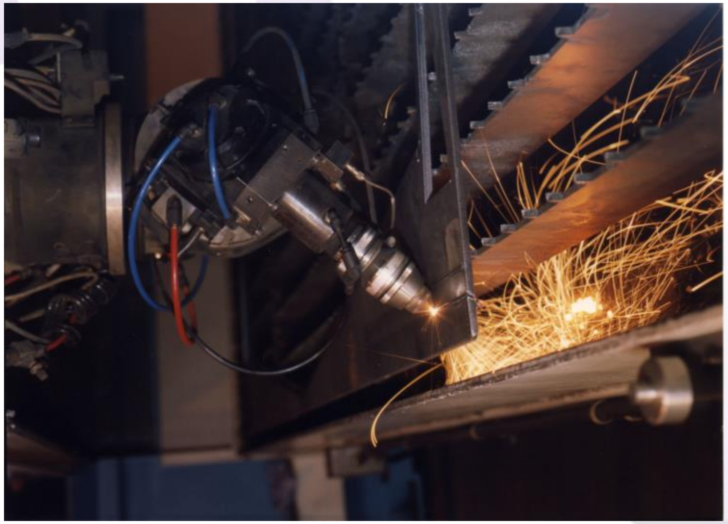
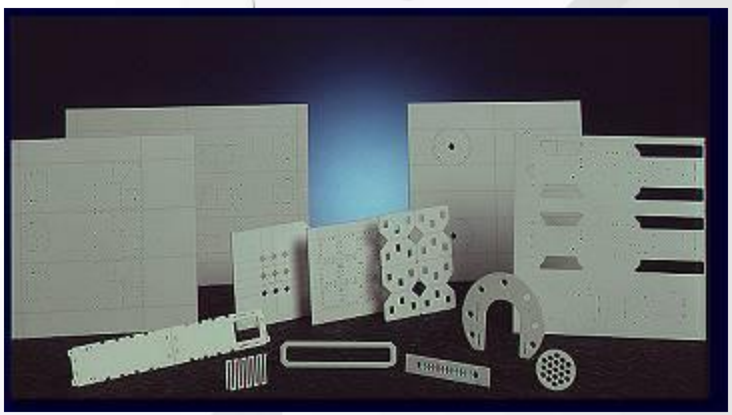
Laser Cutting Nd-YAG & CO_2

Laser cutting of sheet metal is now widely accepted, up to 20 mm thick

Laser cutting of tubes





Laser cutting and scribing of ceramics, eg. alumina

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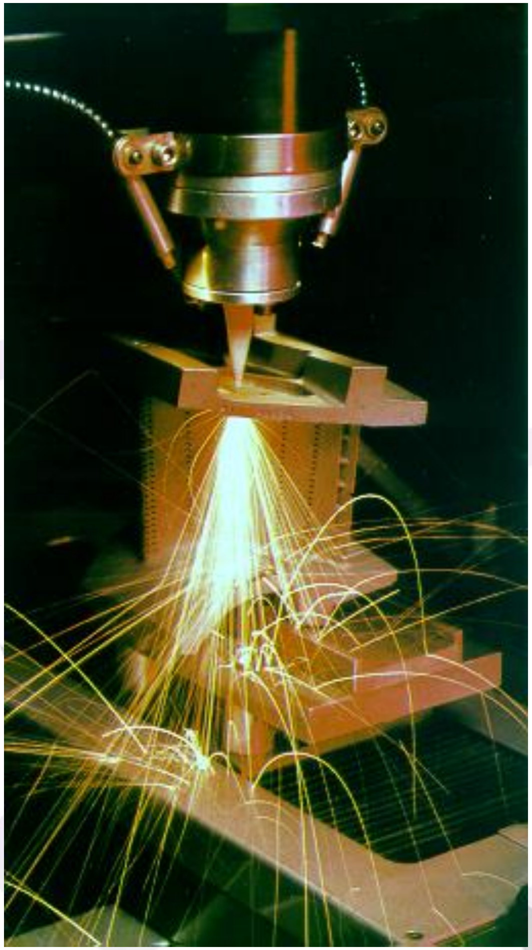
Nd-YAG Laser Drilling of Refractory metals



Jet-engine turbine blade
- Nimonic alloy

0.5 mm holes at 20 degrees to the surface
in a jet engine combustion chamber

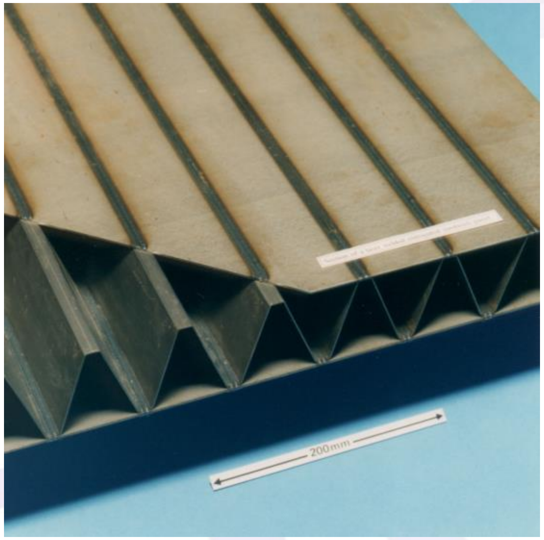
Nd-YAG Laser Welding

Car Body Welding

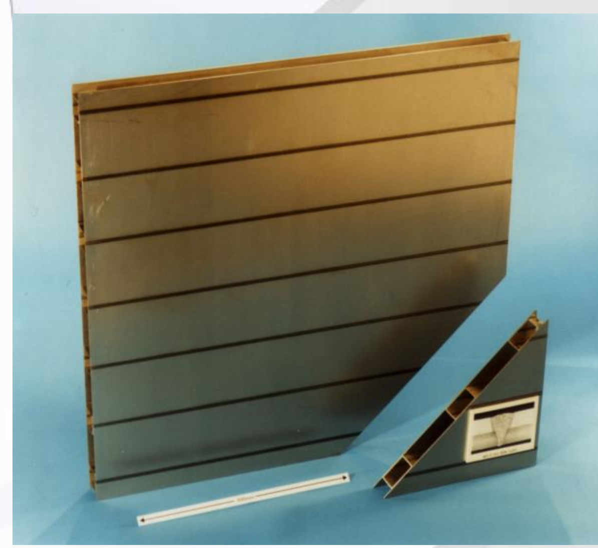
Laser Welded Tailored Blank

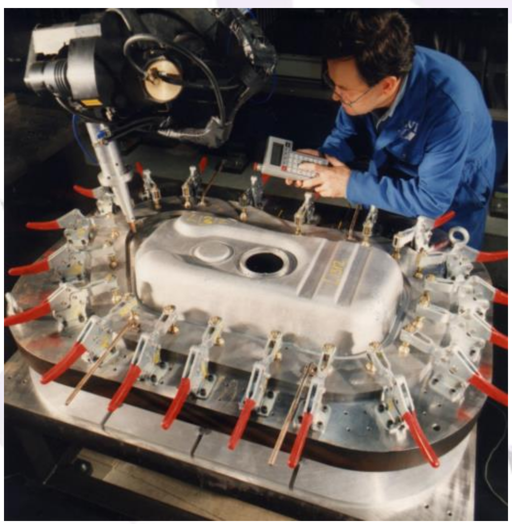
Laser Welded Car Door

Laser Welding



Light weight sandwich panel



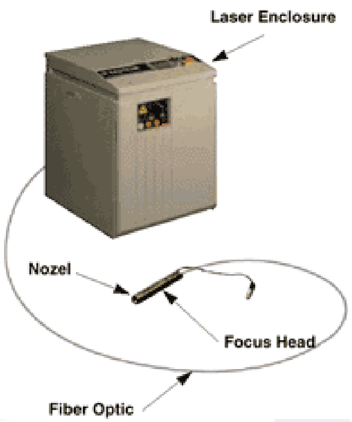


5 axis CO_2 laser welding of a petrol tank

Arc assisted laser welding

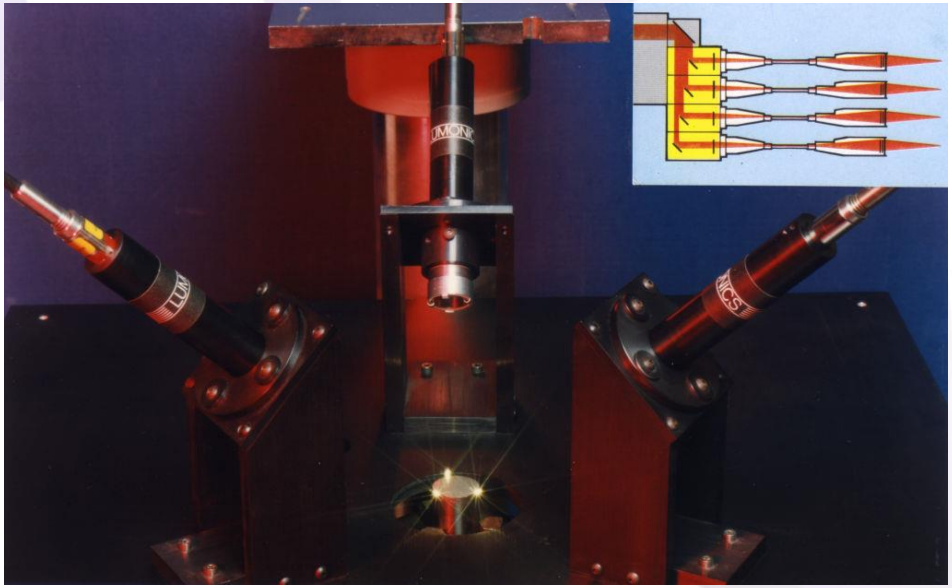
Technology Hub

Nd-Yag Laser Welding



Airbag detonator hermetically welded

Fuel Injector Elements



Hermetically welded pacemaker

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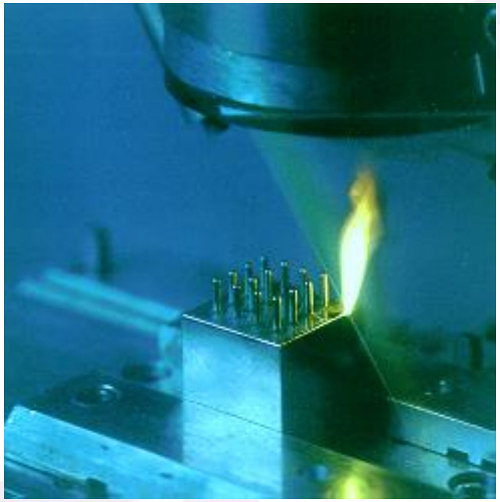
Nd-Yag Laser Welding



Seam welding of relay cans. The The low heat input prevents damage to the adjacent glass to metal seals.

Ball bearing cage. A two fibre system heats both sides of the weld simultaneously

Shadow mask of TV tube welded to its support structure. Alignment is maintained to 5μm

This diaphragm is only 0.04 mm thick. The component is welded at 15 mm/s without buckling

Welding silicon iron motor laminations eases handling prior to winding.

Welding of battery terminals

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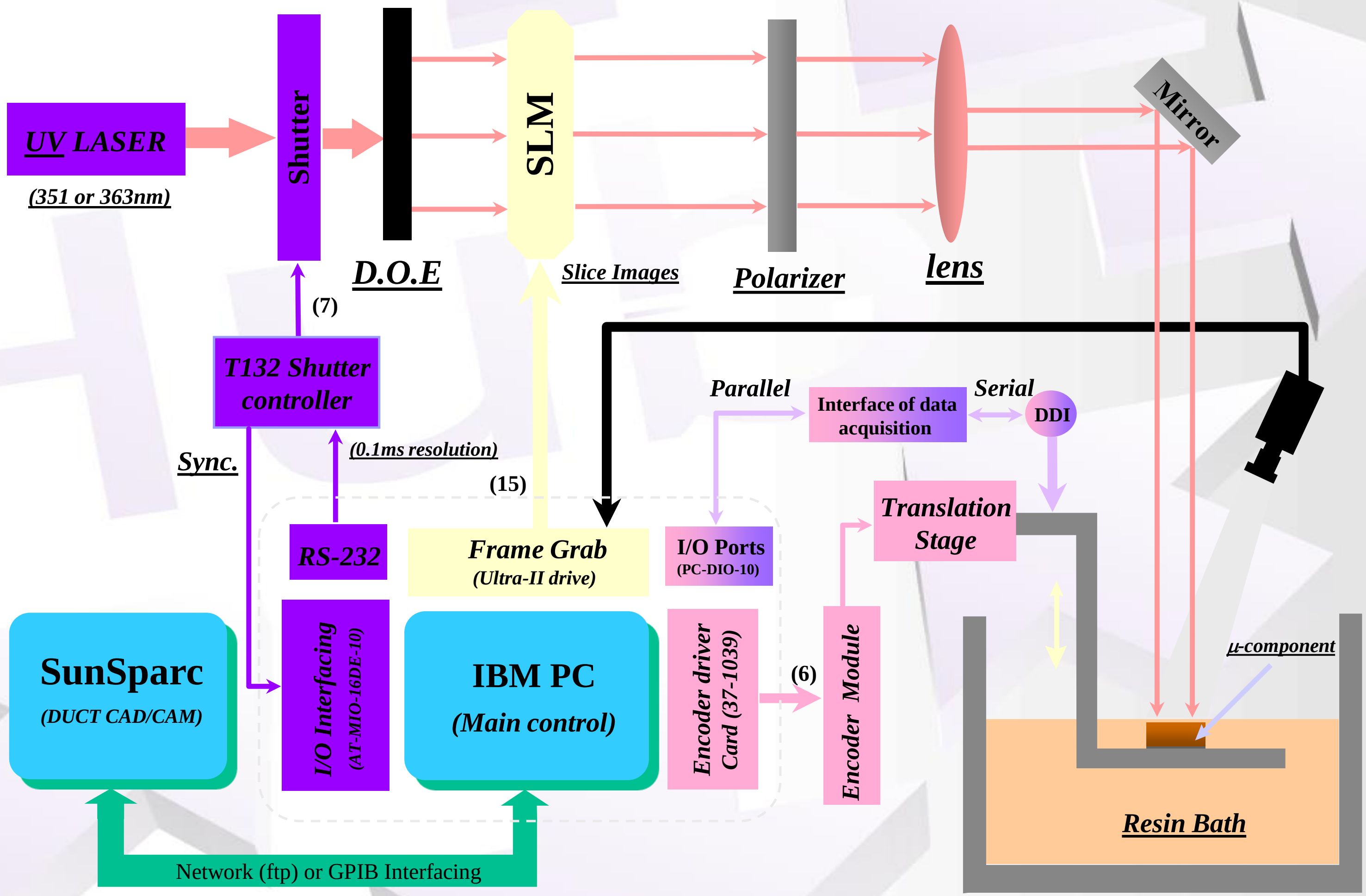
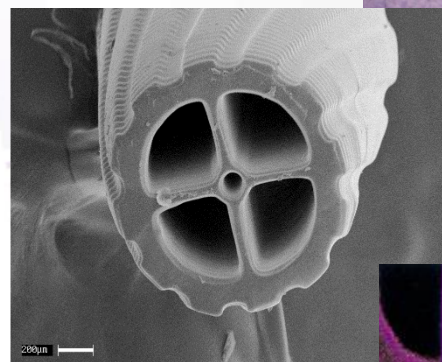
Micro-Stereolithography Experimental Set-up

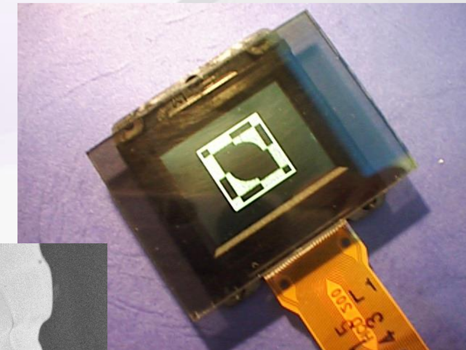
Microstereolithography System Diagram



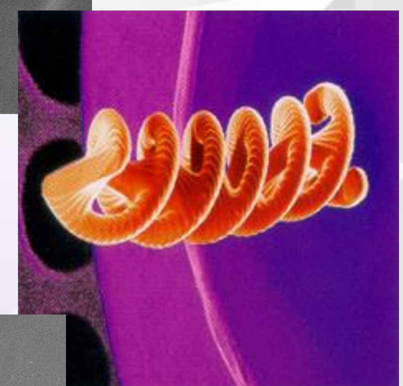
Micro-component Prototyping

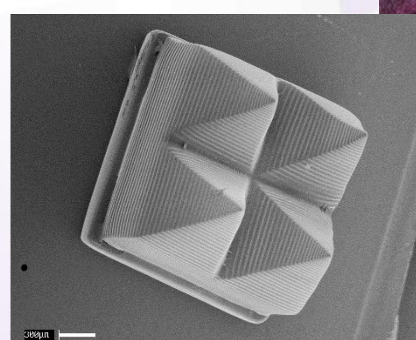
Microstereolithography System





SVGA SLM 800x600 pixels





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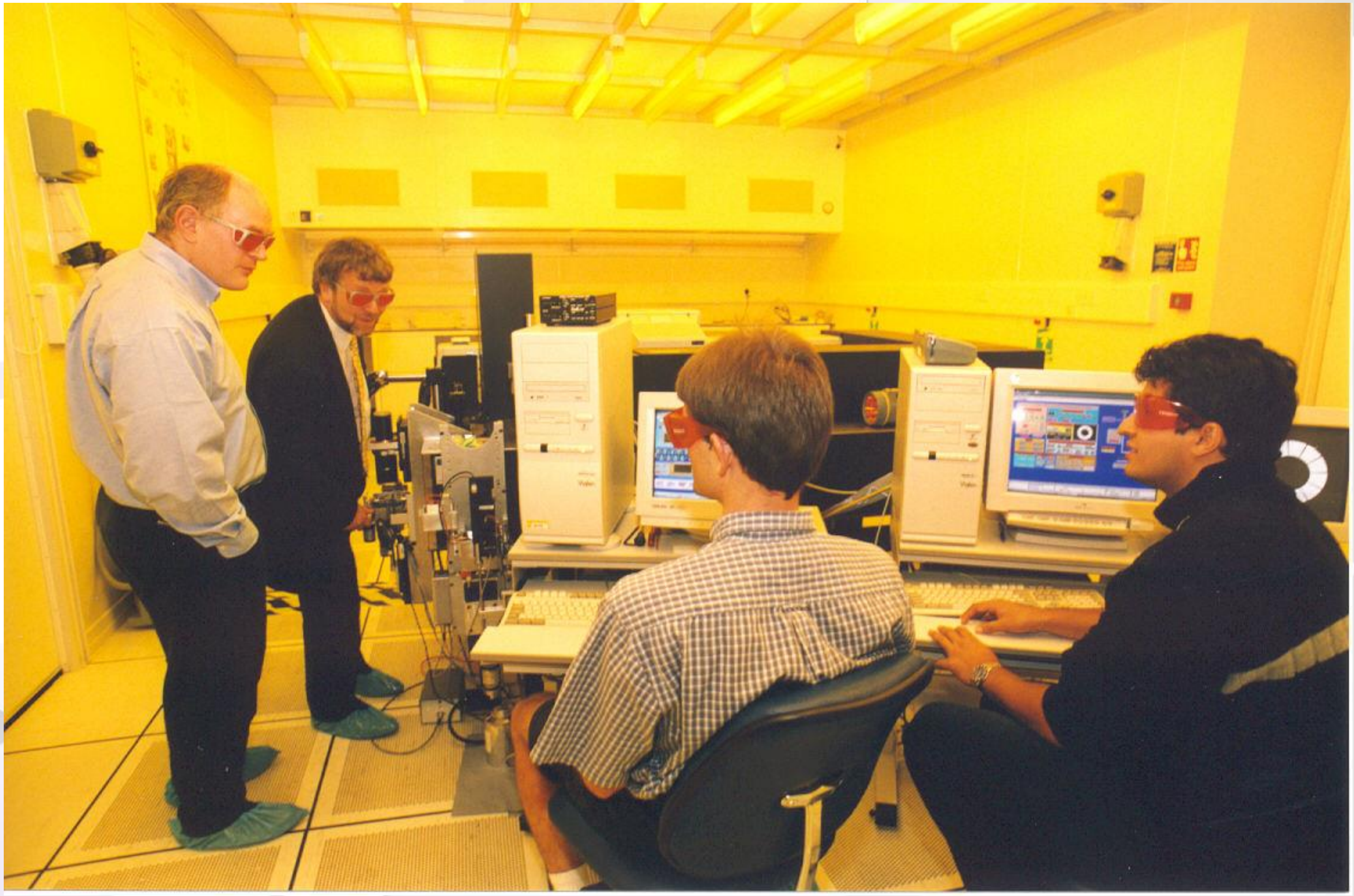
MicroSLA System



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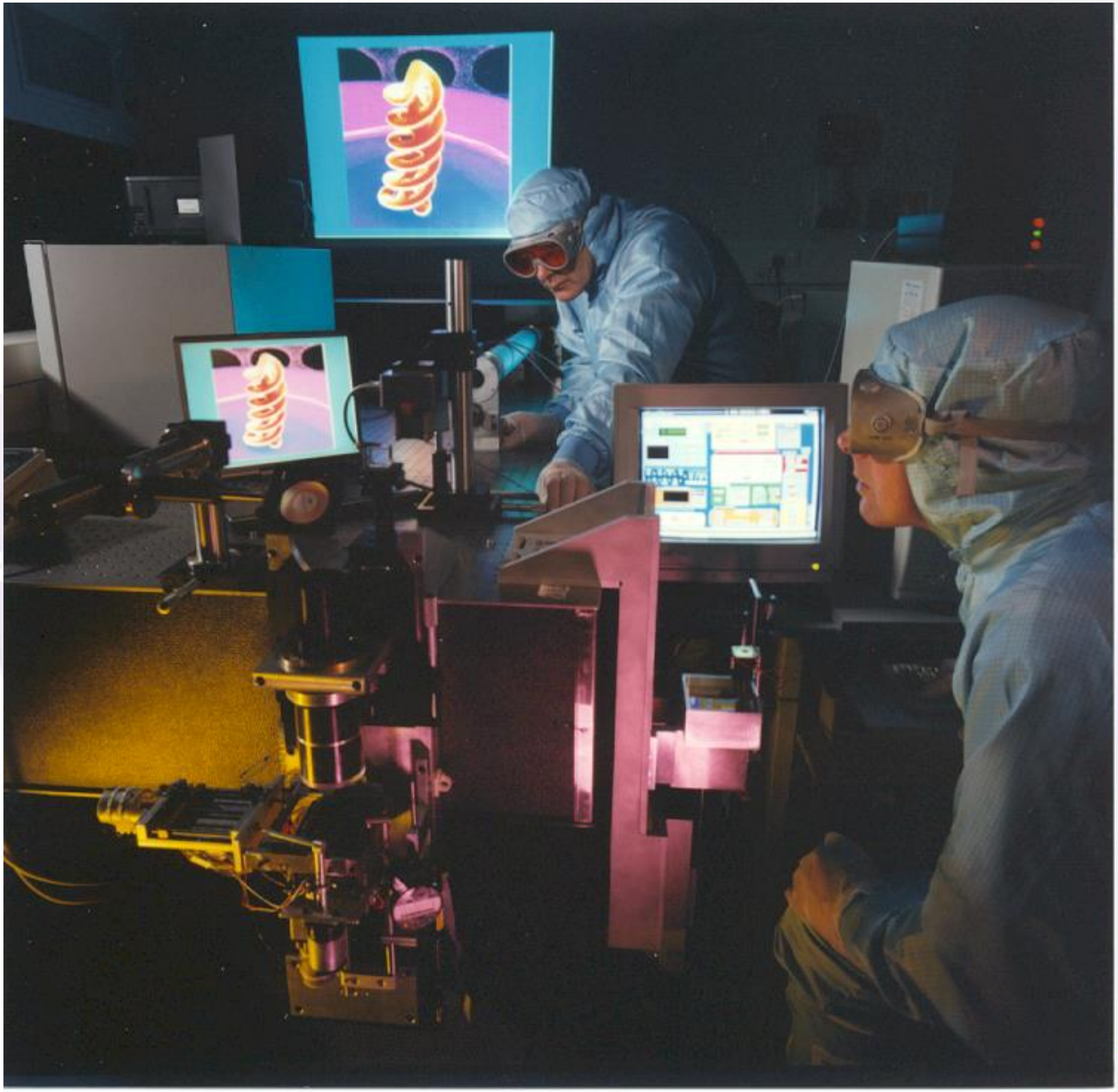
MicroSLA System



Micro-SLA System

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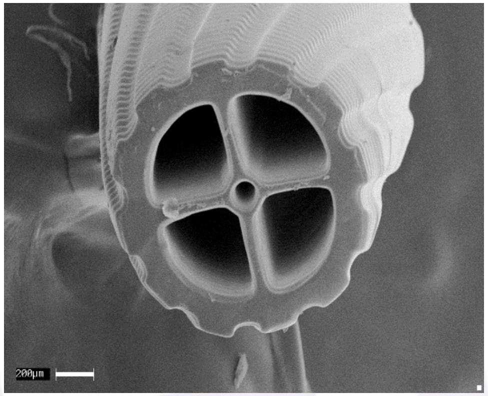
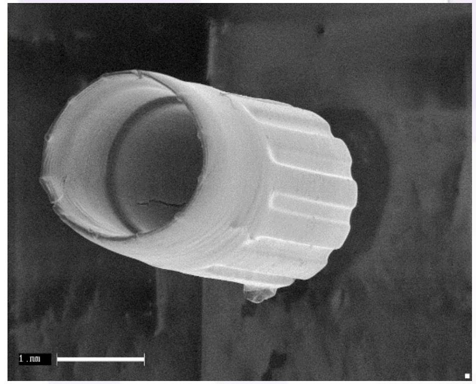
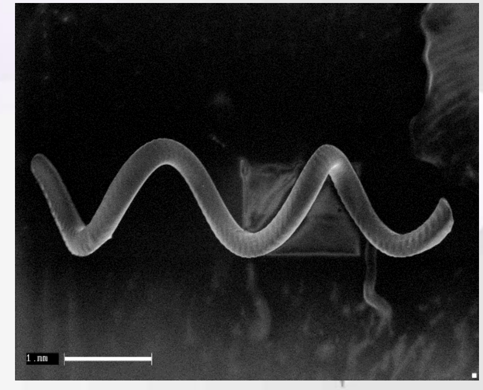
Micro-components



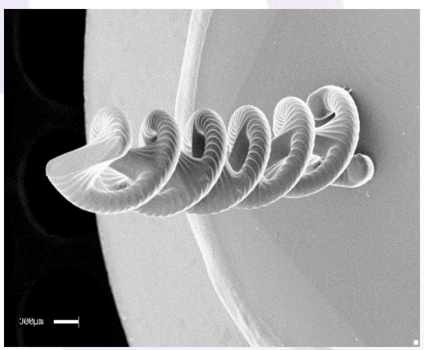
A micro-gear (50 micron layers)



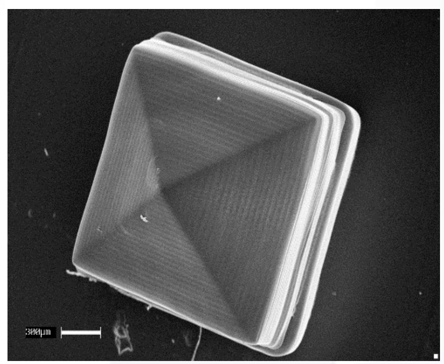
Micro-motor case (50 micron layers)



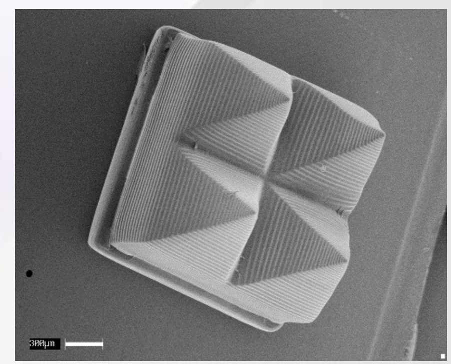
A helix (50 micron layers)



Double helix (50 micron layers)



Micro-pyramid (35 micron layers)

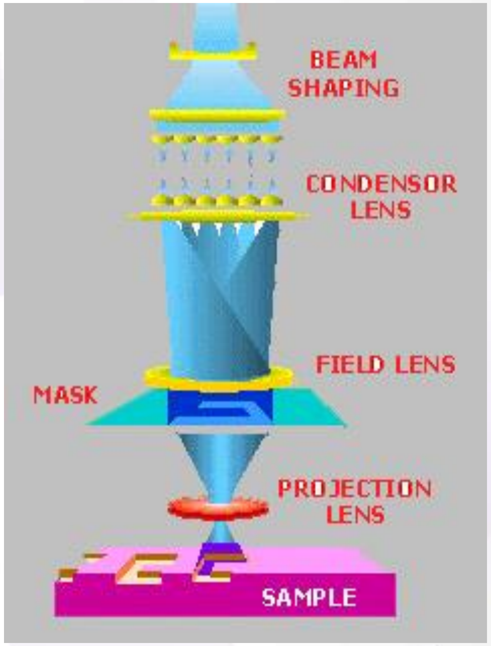


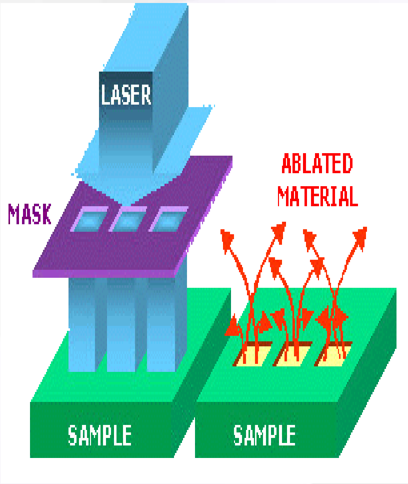
Micro-pyramids (50 micron layers)

Technology Hub

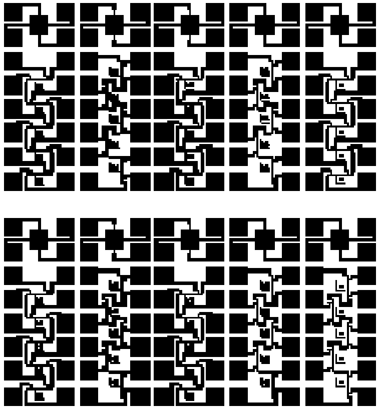
Micromachining - Electronics & Sensors

Lambda Physik LPX 201i, 125W mean power, 2.5J/pulse,100 Hz prf, 10 to 50 ns pulse width





Micro-fluidic systems



Chrome on Quartz Mask

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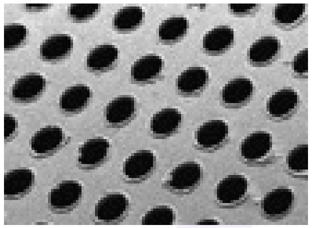
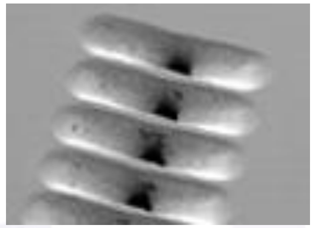
Excimer Laser Micro-Machining

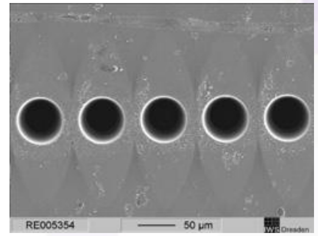
PCB Drilling



Printer Nozzles



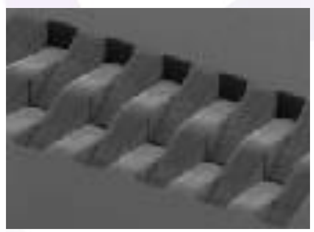
720 dpi nozzle holes



Micro-Fluidic Systems

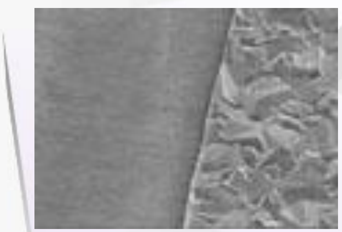
Biomedical Devices

Microstructuring

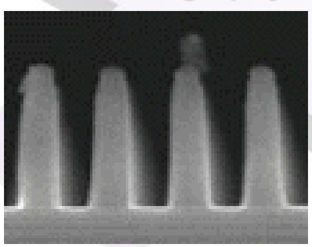


Fibre Gratings

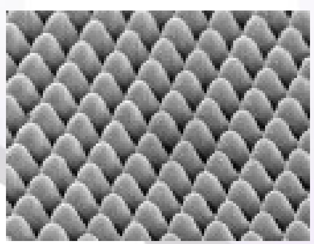
Diamond Smoothing



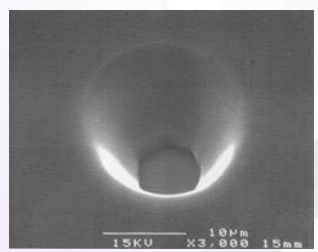
DUV Lithography



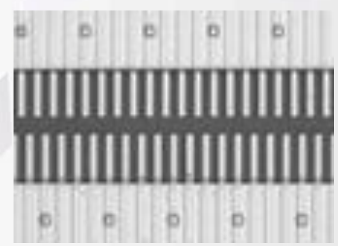
A-R Surface



Tapered micro-via



Sensors



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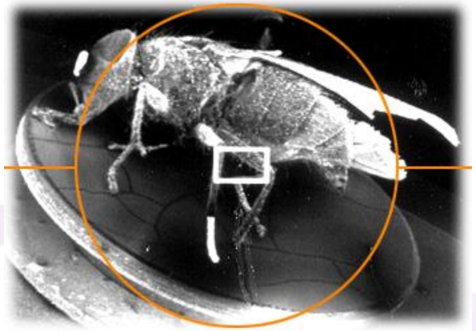
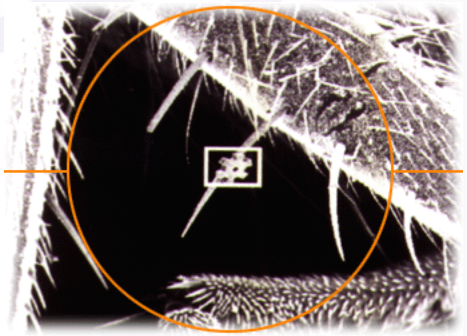
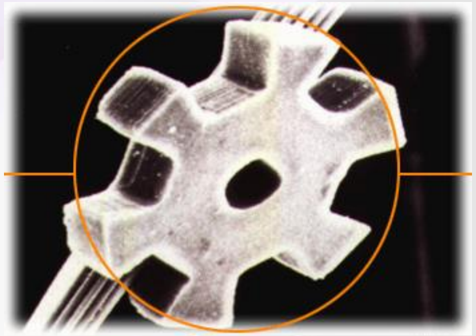
Excimer Laser Micromachining





Gear 50 microns diameter



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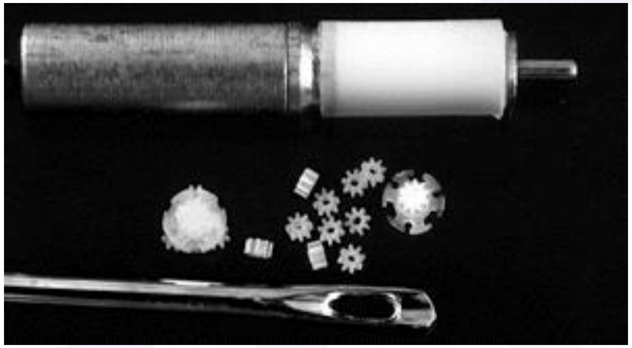
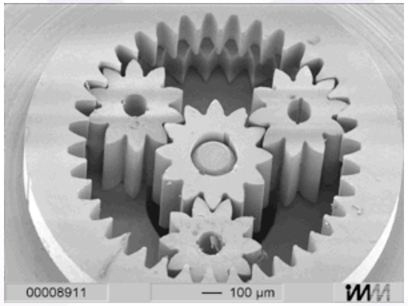
Micro-engineering Application



With a diameter of only 1.9 millimeters the electromagnetic motors can reach an incredible revolution speed of nearly 500,000 rpm.

They are also used for scanners, drive units in heart catheters and high-tech display systems.



The integrated planetary gear system converts low torque at high rotational speed into high torque at correspondingly lower rotational speed.

With a length of 24 mm and a weight of 0.4 grams the helicopter takes off at 40,000 rpm.

Institute of Microtechnology Mainz

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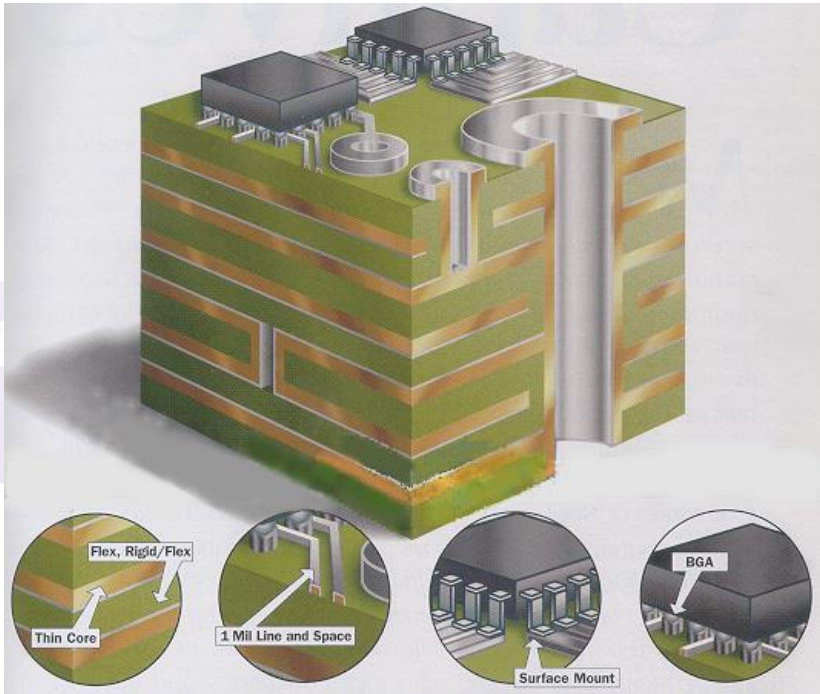
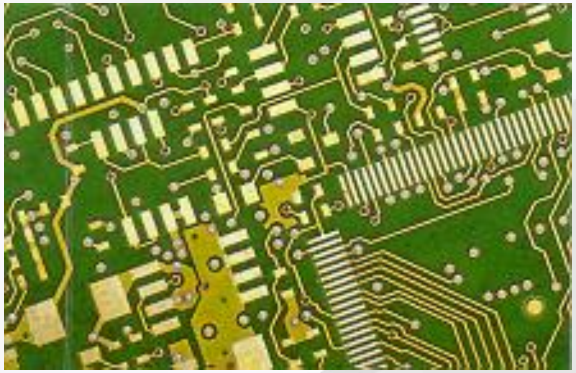
Micrometric Electronics





Circuit board blind vias

Miniaturised Electronic Products

Quality, Reliability & Impedance Matching are all much more difficult

Blind and Micro-via drilling

Multi Laser (CO_2 /Nd: YAG)

Drills both copper and dielectric

High speed - up to 60,000 holes/minute

The pulsed frequency trippled 3Watt YAG (355nm) laser is used for drilling metals

A wavelength tuned pulsed 80 Watt CO_2 (9.6 microns)laser is used for removal of dielectric

High speed drilling of blind and microvias in all types of multilayer printed circuit boards (PCB's), and multichip modules (MCM's) for panel sizes up to 24" x 28".

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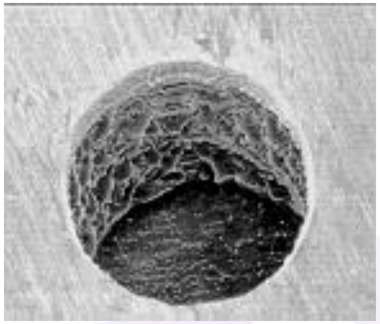
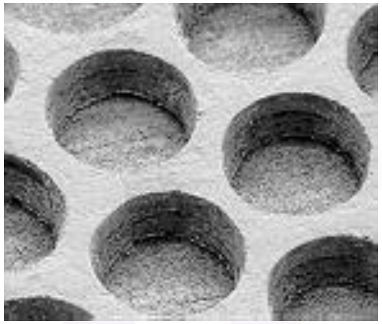
Blind and Micro-via drilling

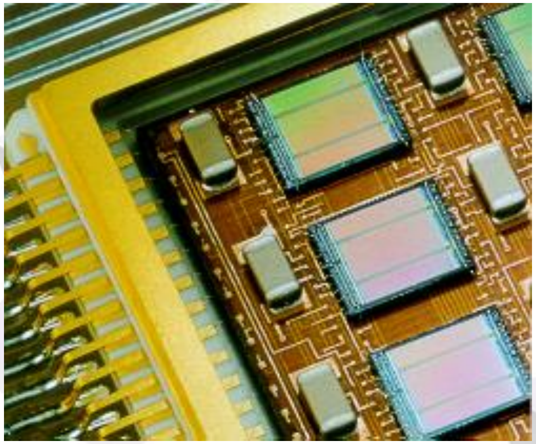


200 µm blind via - 18µm top copper - 125 µm FR4 - laser cleaned bottom copper



Array of 125 µm blind vias in 25 µm polyimide - pre-patterned top copper

Through holes and annular rings



25 µm blind vias

Miniaturised Electronic Products

Concurrent Engineering

Definition of product need: Marketing information

Conceptual design and evaluation

Design; Design analysis; codes/standards review; physical and analytical models

Prototype production; testing & evaluation

Production drawings; Instruction manuals

Material specification; process and equipment selection; safety review; environmental impact

Pilot production

Production

Inspection and quality assurance

Packaging; marketing; and sales literature

Product Supply (JIT)

Increasingly not a single organisation but a supply-chain facilitated by the **Internet and e-commerce**

Computer Aided:
Design (CAD, ECAD);
Engineering (CAE)

Computer Aided:
Manufacture (CAM);
Process Planning (CAPP)

Computer Integrated Manufacture (CIM)

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3) M Farsari, S Huang, RCD Young, MI Heywood, PJB Morrell, CR Chatwin, "Four-wave mixing studies of UV curable resins for microstereolithography," Journal of Photochemistry and Photobiology A: Chemistry 115 (1), 81-87, 1998
4) M Farsari, S Huang, P Birch, F Claret-Tournier, R Young, D Budgett, "Microfabrication by use of a spatial light modulator in the ultraviolet: experimental results," optics letters 24 (8), 549-550, 1999
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8) M Farsari, F Claret-Tournier, S Huang, CR Chatwin, DM Budgett, "A novel high-accuracy microstereolithography method employing an adaptive electro-optic mask," Journal of Materials processing technology 107 (1), 167-172, 2000
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11) P Birch, R Young, M Farsari, C Chatwin, D Budgett, "A comparison of the iterative Fourier transform method and evolutionary algorithms for the design of diffractive optical elements," Optics and Lasers in engineering 33 (6), 439-448, 2000
12) P Birch, R Young, D Budgett, C Chatwin, "Dynamic complex wave-front modulation with an analog spatial light modulator," Optics letters 26 (12), 920-922, 2001

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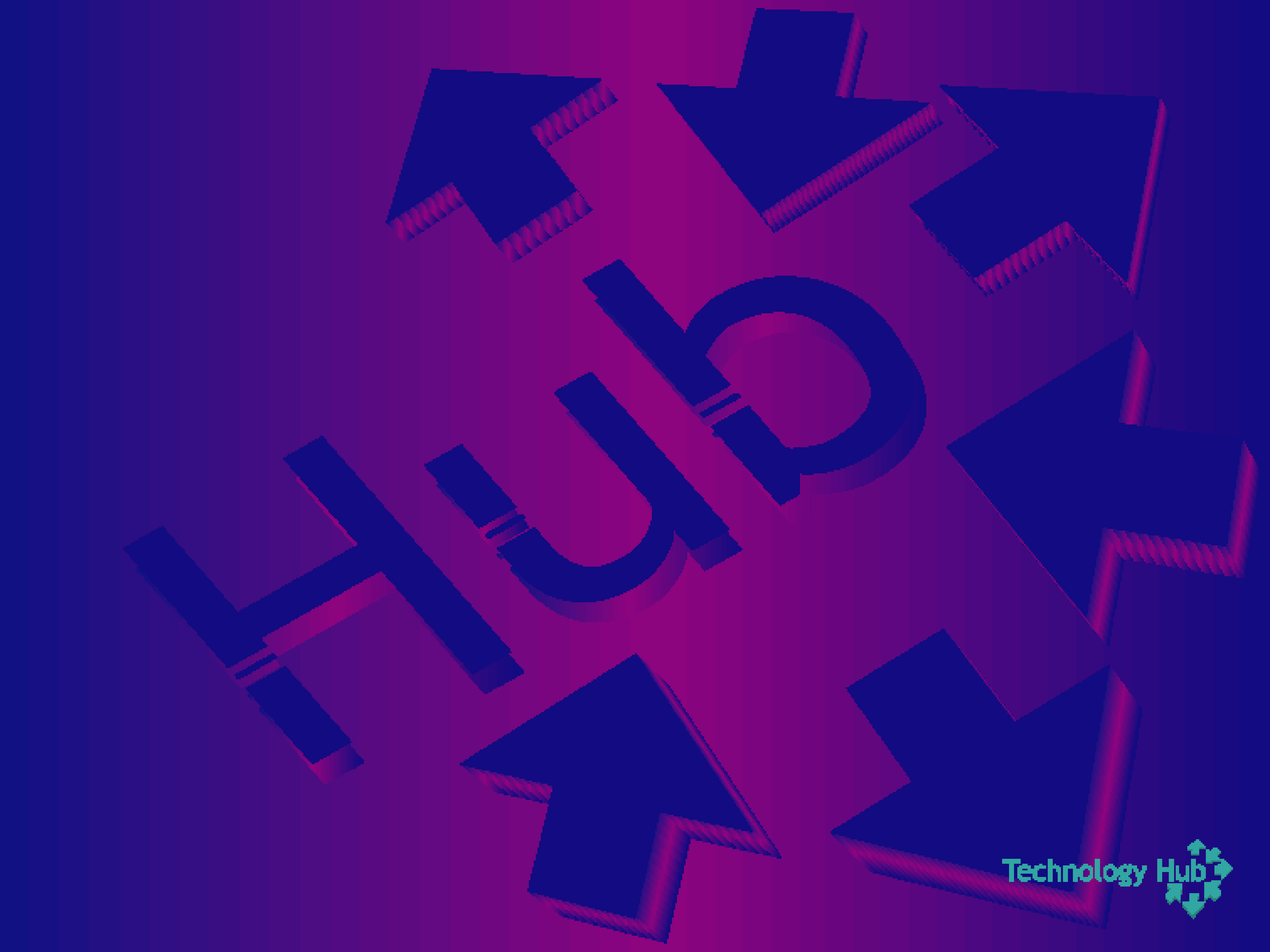
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